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Impact of $PM_{2.5}$ derived from dust events on daily outpatient numbers for respiratory and cardiovascular diseases in Wuwei, China

Quanxi Zhang, Jian Zhang, Zhenhua Yang, Yuexia Zhang, Ziqiang Meng*

Institute of Environmental Medicine and Toxicology, Research Center of Environmental Science and Engineering, Shanxi University, Taiyuan 030006, China

Abstract

The aim of this study is to explore the association between $PM_{2.5}$ (particulate matter with aerodynamic diameter less than 2.5 μm) and daily outpatient number for respiratory and cardiovascular diseases in a place where dust events are most frequent. During the study period, all hospitals in Wuwei, Gansu province, northwest of China were selected. The results suggest that there were associations between $PM_{2.5}$ and the increasing of respiratory and cardiovascular diseases outpatient visits for males and females during the period when dust events frequently happen. $PM_{2.5}$ was one of the main hazardous factors for these diseases during the study period.

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Keywords: dust events; PM2.5; daily outpatient number; respiratory diseases; cardiovascular diseases

1. Introduction

Atmospheric particulate matter constitutes an important component of air pollution. Epidemiological studies have reported a positive correlation between particulate matter concentrations and the increased incidence of human morbidity and mortality [1, 2]. Of particular concern is $PM_{2.5}$ (particulate matter with aerodynamic diameter less than 2.5 μm), which is comprised of particles that readily penetrate to the lower respiratory tract and cause damage to cells.

Dust storms become more and more concerned not only due to their effects on both regional and global environment, but also due to detrimental effects on human health made by dust particulate matter [3]. Epidemiological studies have found that respiratory diseases and mortality, cardiovascular diseases in the

* Corresponding Author. Tel/Fax: +86-0351-7011895.
E-mail address: zqmeng@sxu.edu.cn.

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elderly and even Al Eskan disease (or Desert Storm pneumonitis) were associated with dust storms [4, 5]. Dust events, especially Asian Dust Storms (ADS), are paid more attention because of their frequent occurrence, especially in the spring. During ADS, the mass concentrations of ambient total suspended particulate, PM_{10} (particulate matter with aerodynamic diameter less than 10 μm) and $PM_{2.5}$ are significantly enhanced in comparison with those on non-dust events days. For example, during dust storm events occurring on April 6 and 25, 2000 in Beijing, the concentration of PM_{10} reached as high as 1500 μg m^{-3}, which was 5-10 times higher than that on non-dust storm days [6]. However, particulate matter in these cities is different from that in source regions of dust storms due to industrial activity, large numbers of vehicles and inhabitants, while the source regions of dust storms are usually deserts and far away from industrial civilization. It is possible that the health effects associated with dust events involving naturally-derived particulate matter are different from those associated with anthropogenically-derived particles [7]. Hence, it is necessary to study the health effects of ADS. In order to investigate the effects of naturally-derived particulate matter during dust events days on respiratory and cardiovascular systems, we chose Wuwei of Gansu Province as our study site.

Wuwei (101°49'—104°43'E longitude, 36°29'—39°27'N latitude), which is near the Badain Jaran Desert and Tengger Desert, is frequently disturbed by dust events, especially blowing dust and dust storms [8]. There are few factories and industrial pollutants in the district and the local people live on farming. It is an ideal candidate site to study the effects of naturally-derived dust events on health. When the dust events happen, the average mass concentrations of local ambient $PM_{2.5}$ was often above 150 μg m^{-3}, about 2-3 times the concentrations during non-dust-event days. Based on the meteorological data provided by Wuwei Meteorological Administration and outpatient data on respiratory and cardiovascular patients collected in local hospitals, we used the time-series analysis method to investigate the association of $PM_{2.5}$ during dust events days with daily outpatient number for respiratory and cardiovascular diseases by controlling for long-term temporal trends, day of the week, meteorological factors.

2. Material and methods

2.1. Data

We obtained the daily outpatient numbers of respiratory and cardiovascular diseases (from March 1^{st} to May 31^{st} in 2004 and 2005) from all hospitals in Wuwei, Gansu province, northwest of China. Dust events frequently happen from March 1^{st} to May 31^{st} every year in Wuwei, China, so we chose these three months as the study period. The study subjects included all people who were diagnosed respiratory or cardiovascular disease (International Classification of Diseases Tenth Revision, ICD-10) during the study period. These counts included (1) total respiratory diseases (ICD-10: J00-J99), and the subgroups of the respiratory diseases: upper respiratory tract infection (URTI, ICD-10: J00-J06) and pneumonia (ICD-10: J12-J18); (2) total cardiovascular diseases (ICD-10: I00-I51), and the subgroups: hypertension (ICD-10: I10-I15) and ischemic heart diseases (ICD-10: I20-I25). The numbers of daily respiratory and cardiovascular outpatient visits due to accidents or postoperative infection were excluded from the analysis.

At the same time, data for the date of dust events and daily meteorological measurements such as air temperature (℃), air pressure (hPa), wind speed (m/s) and relative humidity (%) were provided by Wuwei Meteorological Administration. The data for concentrations of daily airborne pollutants such as $PM_{2.5}$, SO_2 and NO_2 were provided by Wuwei Environmental Monitoring Station.

Wuwei Environment Monitoring Station is one of the Chinese executives for the Wuwei Air Quality Monitoring System. There are 6 air monitoring sites within Wuwei. Air pollution data were measured at all 6 monitoring sites. Daily measurements from these sites were averaged to generate an overall exposure estimate for the population in Wuwei.

2.2. Analysis models

Generalized additive Poisson regressions (GAM) were fitted to the logarithm of the expected values of daily respiratory and cardiovascular outpatient numbers respectively as the sum of the smoothed and linear functions of the predictor variable [9]. A smoothed function is a nonparametric tool that allows one to control for potential nonlinear dependency of the variable of interest on covariates such as long-term temporal trends and meteorological factors. The equation was as following:

$$\ln[E(Y_k)] = \alpha + DOW + \beta X_k + s(time) + s(Z_k)$$

where the subscript k refers to the day of the study; $E(Y_k)$ is the expected value of numbers of daily respiratory or cardiovascular outpatients; α is the intercept term; *DOW* is the indicator variables for the day of the week; as the dummy variable, X_k is the concentration of airborne pollutants, such as $PM_{2.5}$, SO_2 and NO_2 on day k;β is the regression coefficient; the s (time) is smoothed function of time, and s (Z_k) are smoothed functions of the meteorological variables (temperature, pressure, wind speed and relative humidity) on day k. The smoothed functions are represented using smoothing splines, and the calculated regression coefficients β were converted to a 'relative risk (RR)' using equation e^{β} and the 95% confidence interval (95% CI) also were estimated assuming normality of the residuals.

We inserted autoregressive terms into the model to remove serial correlations of residuals, in an effect to control for any confounding effect caused by omitted time-dependent covariates. We considered air pollution variables to be linear in the models to obtain estimates of relative risk easily. However, the assumption of the linearity between the log of outpatient visits and air pollution may be not be accurate. Therefore, we added the effect of each pollutant to the basic model using a smoothing function when we analyzed the relationship between air pollution and outpatient visits. We adopted loess, a moving regression smoother, as the nonparametric function in our analysis, s(z) were smooth parameters (span) of calendar time, minimum temperature, minimum pressure, maximum wind speed and minimum relative humidity. The selection criterion of goodness of fit was assessed using Akaike's information criteria [10].

We excluded air pollutant levels exceeding 6 standard deviations above the mean to minimize the effects of pollutant extremes. In this paper, not only $PM_{2.5}$, SO_2, NO_2 were singly introduced to GAM model to estimate the effects of each pollutant on the respiratory and cardiovascular outpatient numbers (single-pollutant model), but also $PM_{2.5}$ and gaseous pollutants (SO_2 and/or NO_2) were introduced to GAM model at the same time to estimate the effects of $PM_{2.5}$ after adjusting for SO_2 and/or NO_2 (multi-pollutant model) to find the main hazardous factor for the respiratory and cardiovascular system. Using the daily concentration and up to 6-day delayed of each pollutant were tested, single-pollutant models, as well as co-pollutants and multi-pollutants models be fitted. These lag periods were selected a priori in order to investigate the short-term effects of dust events on respiratory and cardiovascular outpatient numbers. Results were presented as relative risks (RR) for all pollutants, and the percentage increases in outpatient visits for interquartile range (IQR) increases in air pollution concentrations.

All analyses were performed using the S-plus 2000 software package.

3. Results

3.1. Descriptive Analysis of the Number of Daily Respiratory and Cardiovascular Outpatient

Table 1 shows the daily respiratory and cardiovascular outpatient numbers in Wuwei during the study period in 2004 and 2005. There were a total of 26,635 non-accidental respiratory outpatient visits and 5,405 non-accidental cardiovascular outpatient visits during the study period. The ratio of male to female was 1:0.88 during the study period. For the most part, these calculations indicated that the density functions for each disease could be assumed to be Poisson distributed.

Table 1. Descriptive analysis of daily respiratory and cardiovascular outpatient number form March 1st to May 31st in 2004 and 2005, Wuwei.

Year	Classification	Sex	n	Mean	SD	Min	Max
2004	Respiratory diseases	male	7208	78.35	27.09	26	140
		female	5734	62.33	23.94	12	145
	Cardiovascular diseases	male	1346	14.63	6.34	1	27
		female	1466	15.93	6.82	1	31
2005	Respiratory diseases	male	7389	80.31	29.39	18	155
		female	6303	68.51	23.52	21	140
	Cardiovascular diseases	male	1092	11.87	5.79	1	30
		female	1501	16.32	7.68	1	40

3.2. Descriptive analysis of airborne pollutants and meteorologic measurem ents

Table 2 gives the daily average values of airborne pollutants and meteorologic measurements in Wuwei on dust events and non-dust events form March 1st to May 31st in 2004 and 2005. The results showed that the concentrations of $PM_{2.5}$ during dust storm days were remarkably higher than those on non-dust event days. However, for the concentrations of SO_2 and NO_2, there were non-significant difference between dust event days and non-dust event days. The wind speed on dust event days was remarkably higher than those on non-dust event days. For other meteorologic measurements, there were non-significant difference between dust event days and non-dust event days.

Table 2. Comparison of daily averages of airborne pollutants and meteorologic measurements between dust events and non-dust events form March 1st to May 31st in 2004 and 2005, in Wuwei.

Year	Weather condition	Air pressure (hPa)	Air tempera -ture (℃)	Relative humidity (%)	$PM_{2.5}$ (μg/m^3)	SO_2 (μg/m^3)	NO_2 (μg/m^3)
2004	Non-dust events	845.7±4.9	12.1±6.5	34.5±13.7	75.8±26.9	33.0±19.8	12.8±4.8
	Dust storm	846.2±1.9	5.4±5.7	28.0±1.4	171.3±16.6**	50.6±14.7	15.9±0.1
2005	Non-dust events	851.2±14.0	10.6±7.3	41.0±14.1	82.3± 15.9	34.8±26.7	12.3±4.0
	Dust storm	850.2±22.9	10.8±7.5	38.2±6.5	189±163**	36.7±3.7	8.0±1.5

Note: Each index is the average concentrations of 24 h; One Nova was used, $*P \le 0.05$, $**P \le 0.01$ when compared to the non-dust storm; Each data is the mean ± SD.

3.3. Results of three pollutant models

Tables 3 and 4 show the relative risks of the association between $PM_{2.5}$, NO_2, SO_2 and daily respiratory and cardiovascular outpatient number in three pollutant models, respectively. Results were presented as RR for all pollutants, and the percentage increases in outpatient visits for IQR increases in air pollution concentrations.

Table 3. Relative risks of the association between $PM_{2.5}$, NO_2, SO_2 and daily respiratory outpatient number in three pollutant models.

Diseases	Sex	Airborne pollutants (the best lag day)	single-pollutant model	co-pollutant model			multi-pollutant model
				$PM_{2.5}$	NO_2	SO_2	
Total respiratory diseases	Male	$PM_{2.5}$(2)	1.289(1.019,1.891)*	-	1.246(1.078,1.681)*	1.144(1.027,1.507)*	1.217(1.08,1.606)*
		NO_2(5)	1.045(0.982,1.112)	1.008(0.98,1.037)	-	1.016(0.986,1.046)	0.978(0.95,1.008)
		SO_2(4)	1.195(1.037,1.378)*	1.086(0.891,1.323)	1.133(0.964,1.33)	-	1.156(0.991,1.347)
	Female	$PM_{2.5}$(1)	1.232(1.078,1.408)*	-	1.207(1.062,1.372)*	1.192(1.032,1.376)*	1.175(1.025,1.347)*
		NO_2(5)	1.025(0.971,1.082)	1.029(0.995,1.063)	-	1.016(0.968,1.067)	1.029(0.98,1.081)
		SO_2(5)	1.151(1.02,1.299)*	1.081(0.939,1.244)	1.146(0.998,1.318)	-	1.119(0.987,1.269)
URTI	Male	$PM_{2.5}$(2)	1.103(1.042,1.167)*	-	1.081(1.018,1.148)*	1.072(1.004,1.144)*	1.09(1.026,1.158)*
		NO_2(4)	1.093(1.031,1.158)*	1.042(0.978,1.111)	-	1.064(0.996,1.136)	1.058(0.993,1.127)
		SO_2(3)	1.163(0.917,1.476)	1.032(0.998,1.068)	1.012(0.982,1.042)	-	1.014(0.983,1.046)
	Female	$PM_{2.5}$(2)	1.141(1.07,1.217)*	-	1.119(1.016,1.231)*	1.078(1.003,1.159)*	1.102(1.027,1.183)*
		NO_2(0)	1.097(0.998,1.205)	1.093(0.984,1.215)	-	1.085(0.982,1.199)	1.059(0.961,1.167)
		SO_2(3)	1.207(1.032,1.411)*	1.023(0.961,1.089)	1.053(0.995,1.114)	-	1.011(0.943,1.084)
Pneumonia	Male	$PM_{2.5}$(3)	1.117(1.025,1.216)*	-	1.068(0.965,1.181)	1.083(0.99,1.184)	1.106(1.007,1.215)*
		NO_2(6)	1.052(0.948,1.168)	1.014(0.951,1.082)	-	1.03(0.965,1.099)	1.033(0.968,1.102)
		SO_2(1)	1.227(0.949,1.587)	1.046(0.995,1.099)	1.05(0.974,1.131)	-	1.035(0.992,1.079)
	Female	$PM_{2.5}$(2)	1.15(1.014,1.304)*	-	1.082(0.954,1.226)	1.036(0.946,1.134)	1.075(0.982,1.177)
		NO_2(6)	1.052(0.98,1.13)	1.011(0.933,1.096)	-	1.024(0.944,1.11)	1.026(0.945,1.113)
		SO_2(6)	1.135(0.944,1.364)	1.053(0.806,1.376)	1.023(0.833,1.256)	-	1.035(0.791,1.353)

Note: * $P \leq 0.05$

As is shown in Table 3, $PM_{2.5}$ with a lag of 2 days and 1 day were significantly associated with total respiratory diseases for males and females, respectively; SO_2 with a lag of 4 days and 5 days were significantly associated with total respiratory diseases for males and females, respectively; there was no significant association between NO_2 and total respiratory diseases. $PM_{2.5}$ with a lag of 2 days was significantly associated with URTI for males and females, respectively; NO_2 with a lag of 4 days for males and SO_2 with a lag of 3 days for females were significantly associated with URTI, respectively. $PM_{2.5}$ with a lag of 3 days and 2 days were significantly associated with pneumonia for males and females, respectively.

From Table 4 we can see that there were significant association between $PM_{2.5}$ with a lag of 3 days and NO_2 with a lag of 2 days and total cardiovascular diseases for both males and females, respectively; SO_2 with a lag of 3 days and 5 days were significantly associated with total cardiovascular diseases for males and females, respectively. $PM_{2.5}$ with a lag of 1 day and 5 days were significantly associated with ischemic heart diseases for males and females, respectively; NO_2 with a lag of 2 days and SO_2 with a lag of 3 days and 5 days were significantly associated with total cardiovascular diseases for males, respectively. $PM_{2.5}$ with a lag of 1 day was significantly associated with hypertension for males.

Table 4. Relative risks of the association between $PM_{2.5}$, NO_2, SO_2 and daily cardiovascular outpatient number in three pollutant models.

Diseases	Sex	Airborne pollutants (the best lag day)	single-pollutant model	Co-pollutant model			Multi-pollutant model
				$PM_{2.5}$	NO_2	SO_2	
Total cardiovascular diseases	Male	$PM_{2.5}$(3)	1.215(1.134,1.389)*	-	1.171(1.087,1.263)*	1.14(1.053,1.234)*	1.146(1.056,1.243)*
		NO_2(2)	1.155(1.038,1.286)*	1.015(0.978,1.054)	-	1.138(1.049,1.235)*	1.13(1.039,1.228)*
		SO_2(3)	1.203(1.023,1.463)*	1.214(1.068,1.38)*	1.26(1.115,1.424)*	-	1.193(1.047,1.36)*
	Female	$PM_{2.5}$(3)	1.127(1.033,1.229)*	-	1.093(1.009,1.185)*	1.092(1.007,1.186)*	1.105(1.017,1.201)*
		NO_2(2)	1.14(1.027,1.265)*	1.012(0.978,1.047)	-	0.99(0.954,1.028)	1.002(0.966,1.039)
		SO_2(5)	1.221(1.038,1.605)*	0.888(0.764,1.033)	0.961(0.838,1.101)	-	0.863(0.737,1.011)
Hypertension	Male	$PM_{2.5}$(1)	1.235(1.089,1.518)*	-	1.168(1.019,1.337)*	1.21(1.046,1.399)*	1.208(1.042,1.402)*
		NO_2(0)	1.185(0.883,1.591)	0.997(0.93,1.07)	-	0.987(0.918,1.06)	0.994(0.924,1.07)
		SO_2(3)	1.219(0.912,1.765)	0.889(0.668,1.182)	0.989(0.785,1.247)	-	0.879(0.659,1.172)
	Female	$PM_{2.5}$(3)	1.117(0.968,1.289)	-	1.01(0.882,1.156)	1.061(0.923,1.221)	1.06(0.917,1.224)
		NO_2(2)	1.01(0.995,1.025)	0.983(0.925,1.046)	-	0.975(0.914,1.041)	0.827(0.447,1.529)
		SO_2(5)	1.05(0.761,1.448)	0.893(0.507,1.573)	0.866(0.683,1.097)	-	0.674(0.361,1.26)
Ischemic heart disease	Male	$PM_{2.5}$(1)	1.217(1.014,1.461)*	-	1.15(1.008,1.311)*	1.065(0.916,1.239)	1.079(0.925,1.259)
		NO_2(2)	1.037(1.009,1.066)*	1.012(0.937,1.092)	-	0.998(0.923,1.079)	1.002(0.926,1.083)
		SO_2(5)	1.203(1.055,1.866)*	1.205(1.008,1.537)*	1.239(1.07,1.576)*	-	1.247(1.006,1.544)*
	Female	$PM_{2.5}$(5)	1.201(1.005,1.436)*	-	1.026(0.858,1.227)	0.999(0.828,1.205)	0.906(0.764,1.074)
		NO_2(4)	1.012(0.994,1.03)	0.996(0.885,1.121)	-	0.88(0.732,1.056)	0.851(0.716,1.01)
		SO_2(5)	1.113(0.878,1.964)	1.189(1.031,1.87)*	1.212(1.06,1.882)	-	1.233(0.947,1.606)

Note: * $P \leq 0.05$

$PM_{2.5}$ and gaseous pollutants (SO_2 and/or NO_2), which had statistically significant changes in single-pollutant model, were introduced to GAM model at the same time to process the co/multi-pollutant model analysis. After adjusting for other pollutants, the effects of some pollutant on daily outpatient visits for respiratory and cardiovascular diseases were analyzed.

Table 3 and 4 also present the RR of the association between $PM_{2.5}$, NO_2, SO_2 and daily respiratory and cardiovascular diseases outpatient number in co-pollutant model and multi-pollutant model, respectively. The results pointed out that, after adjusting for SO_2 and/or NO_2, there was a decreasing effect of $PM_{2.5}$ on daily outpatient number for total respiratory and cardiovascular diseases, respectively, but significant associations were retained all the same. Nevertheless, after adjusting for other pollutants, neither SO_2 nor NO_2 was significantly associated with daily outpatient number for respiratory diseases. After adjusting for other pollutants, SO_2 and NO_2 were significantly associated with daily outpatient number for cardiovascular diseases for males, respectively. However, neither SO_2 nor NO_2 was significantly associated with daily outpatient number for cardiovascular diseases for females.

4. Discussion

Epidemiological studies have reported a positive correlation between particulate matter concentrations and the increased incidence of human morbidity and mortality [11, 12]. However, there is little research on the association between respiratory and cardiovascular health and $PM_{2.5}$ during dust events days in the places which are close to the deserts. The aim of this study is to evaluate the health effects of $PM_{2.5}$ in a location where traffic and industry are underdeveloped and dust events are most frequent in China. The setting allows the opportunity to reduce confounding by anthropogenically-derived particulate matter and to confirm the health effects of naturally-derived $PM_{2.5}$ during dust events days.

Table 2 shows that the concentrations of $PM_{2.5}$ during dust storm days were remarkably higher than those on non-dust event days. However, the concentration of each gaseous pollutant was low at different weather. These results suggested that particulate matter was the main pollution source when the dust events occurred and the health effects of dust events partly relate to the particulate matter of dust events. This is consistent with the studies of Ma et al. and Xie et al., the mass concentration in ADS events was roughly 3-5 times, or even 5-10 times higher than the highest concentration measured in non-ADS days in their studies [6, 13].

We analyzed various pollutant models in an attempt to estimate the independent effect of $PM_{2.5}$ and the possible interaction between $PM_{2.5}$ and the gaseous pollutants present in a mixture rather than separately in the air. Single-pollutant model showed that $PM_{2.5}$ during dust events days was positively associated with increases in the daily numbers of respiratory (URTI, pneumonia) and cardiovascular diseases (hypertension, ischemic heart diseases) outpatient visits, and these associations presented, in general, a short time lag. Multi-pollutant model pointed out that, after adjusting for SO_2 and/or NO_2, there were decreasing effects of $PM_{2.5}$ on daily outpatient number for respiratory and cardiovascular diseases, respectively, but significant associations were retained all the same. Nevertheless, after adjusting for other pollutants, neither SO_2 nor NO_2 was significantly associated with daily outpatient number for respiratory and cardiovascular diseases. These results suggested that $PM_{2.5}$ was one of the main hazardous factors for respiratory and cardiovascular diseases during the study period. This is consistent with some epidemiological studies about $PM_{2.5}$. For example, using time series analysis, Schwartz (2000) found that the percentage increases in all deaths associated with a 10-μg m^{-3} increase in $PM_{2.5}$ was 3.75% (95% CI 3.2-4.3) [12]. Another study showed that each 10-μg m^{-3} increase in annual $PM_{2.5}$ mean concentration, based on a number of different averaging periods, was associated with increase in all-cause, cardiopulmonary, and lung cancer mortality of 4%, 6%, and 8%, respectively [14]. The relationship between $PM_{2.5}$ and adverse health effects was linear and without a discernible lower “safe” threshold. Holguín et al. also found that ambient levels of $PM_{2.5}$ can reduce the high-frequency component of heart rate variability in elderly subjects living in Mexico City and that subjects with underlying hypertension are particularly susceptible to this effect [15].

A thorough identification of high-risk groups for target diseases would be useful to appropriate air quality management [16]. If the epidemiologic associations between $PM_{2.5}$ and respiratory and cardiovascular diseases are causal, it is likely that a frail subgroup is more affected by air pollution than a healthy group. Even though little is known of the characteristics of persons who are susceptible to adverse health effects related to $PM_{2.5}$. Some studies suggest that some subgroups within the population are sensitive to air pollution, such as the elderly or premorbid people [17, 18]. We examined whether the effect of $PM_{2.5}$ on the risks of respiratory and cardiovascular outpatient visits differed depending on sex. Our results showed different associations between $PM_{2.5}$ during dust events days and respiratory and cardiovascular outpatient visits in males and females. Especially for hypertension outpatient visits, $PM_{2.5}$ was significantly associated with them just for males. The reasons for this difference are unclear. However, several authors have suggested possible explanations for existing gender differences observed in health. It is accepted that differences in hormonal status [19] and the differences in sensitivity to effect of smoking are the part of reasons for gender differences in respiratory and cardiovascular diseases [14, 20]. The possible explanation for the gender differences seen in Wuwei maybe that local women pay more attention to prevent harm from dust events. For instance, women are more inclined to stay home during high-concentration particulate days, but most men do not; women are more likely to put on a respirator to protect the respiratory tract on dust event days compared with men; and the majority of women tend to refrain from smoking and drinking more than men.

There are several limitations in the study. Firstly, our study time period was short for a time series analysis. The reason for the short time period is because the main purpose of this paper is to study the effect of $PM_{2.5}$ in a place where dust events are most frequent on daily outpatient visits for respiratory and cardiovascular diseases during the period when dust events frequently happen. Dust events frequently happen from March 1st to May 31st every year in Wuwei, China, so we chose these three months of 2004 and 2005 as the study period. Secondly, we could not control for the effects of infectious disease epidemics because of the limitation of the data. These limitations may have resulted in some bias in the magnitude of the relationship between $PM_{2.5}$ during dust events days and human health outcomes, although we expect that the general trends found would be unchanged.

5. Conclusion

In a word, $PM_{2.5}$ during dust events days was positively associated with increasing of many respiratory and cardiovascular diseases outpatient visits in males and females with the effect across various lags. The effects of $PM_{2.5}$ for males and females are different. For example, males carry great risks of hypertension due to the effect of $PM_{2.5}$. $PM_{2.5}$ was one of the main hazardous factors for respiratory and cardiovascular diseases during the study period.

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